Heindl (Jos. J.) With the compliments of Jos. J. Heindl

REPORT

ON

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OF

Supplying Church Hill with Water

AND ON THE

EXTENSION OF THE WORKS,

BY

JOSEPH J. HEINDL.

March the 4th, 1871.

RICHMOND, VA.
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Richmond, Va., February 28th, 1871.

To Wm. H. Scott, Esq.,

Chairman of Committee on Water Works:

Sir:—In obedience to the request conveyed in your letter of the 8th December last, and in compliance with the City Council's resolution of the 5th of that month, appointing me consulting engineer to advise the best plan of supplying, most effectually and economically, the residents of Church Hill with water, to examine the condition of the water works, and to report such measures as I may deem advisable for increasing their efficiency, I have the honor to report as follows: First, as to a

SUPPLY FOR CHURCH HILL.

Tests were taken during the month of December last, at the intersection of Grace and Twenty-seventh streets, the highest point of that hill, to ascertain the head of water there. The elevation at that point is 46 feet 10 inches below the level of the water in the reservoir. It was found that the maximum head indicated during the day was 13 feet 9½ inches above the curb, and during the night 22 feet 10 inches. From guagings taken at the reservoir during the month of January, the quantity of water consumed during the twelve hours of the days, from 6 A. M. to 6 P. M., was ascertained to be 1,434,130 gallons, and during the twelve hours of the nights, from 6 P. M. to 6 A. M., 1,187,215 gallons. The variation in the monthly consumption during the year, has been, as shown by the annual reports, from 20 to 50 per cent.

It is a well-known principle in hydraulics, that the loss of head, other elements remaining the same, varies as the square of the velocity; or, in other words, as the square of the quantity used. If, therefore, the quantity consumed should be 20 per cent. more than above given, the maximum head (during the night) would be only 10 feet 4 inches above the

curb; and, if the increase should be 50 per cent. more, the head would be 7 feet 2 inches below the curb.

From these facts, it is plain that the present means of supplying Church Hill are already far two small, and they will become less and less adequate with the growing demand of the city. The demand has increased at a greater rate than the population. In the last three years, during which there has been no material growth of population, the consumption increased annually more than 10 per cent. With an increase of business, there will be a still greater increase of consumption, distinct from what may result from an increase of population; and consequently, in less than five years, no head of water would be available at the intersection of Grace and Twenty-seventh streets.

In order, therefore, to an ample provision of water for Church Hill, I recommend that the supply to it should be furnished directly from the reservoir, or from a point as near to the reservoir as possible, through an independent pipe of adequate capacity; thereby entirely separating the supply for Church Hill from the the supply for the lower levels of the city.

Owing to the present location and sizes of the conduit mains which supply the city, much head is lost, which might be available for Church Hill. The 24-inch main now supplying the city, is fed by four mains from the reservoir, whose united area is less than that of the 24-inch main. From this circumstance a material loss of head results. The four conduit mains which feed the 24-inch main are the following, viz: Two 10-inch pipes, each 50 feet long, leading from the western side of the reservoir; and two pipes leading from the eastern side, one of them a 12-inch main, 4,000 feet long, and the other a 10-inch main 4,970 feet long. These last were formerly the supply mains, and run from the reservoir in a straight line through Hollywood to Jefferson and Main streets, whence the 10-inch main is continued to First and Main. The united area of these subsidiary feeding pipes is 348¾ square inches, while the area of the 24-inch main is 452⅜ square inches. It is plain that if this 24-inch main be directly connected with the reservoir, the supply to the city would be proportionately increased. By connecting the 24-inch main directly with the pump mains, when necessary, the city could be supplied from the latter without the intervention of the reservoir.

If this recommendation be adopted, then the mains now laid through Hollywood would be superfluous, and could be used for supplying Church Hill, their capacity being adequate for that purpose.

In executing this plan the 12-inch main should be connected with the 16-inch at Third and Franklin streets; laid thence down Franklin; and extended, with new 12-inch pipe, directly to Twenty-seventh and Grace (8,570 feet). Thence the water could be distributed by the use of the 10-inch main taken from Hollywood. By this means, with a consumption of

36,000 gallons an hour, or 864,000 gallons per day, the head obtained from the present system at that point would be 10 feet, and with a consumption of 80,000 gallons per day, the head would not be less than 30 feet above the curb.

The residents of Church Hill would then receive, from the present system, a fuller supply at a greater head than is now given the residents of Shockoe Hill, and any increase hereafter given to the present head at the reservoir would be as beneficial to them as to other citizens.

I consider it necessary, however, to increase the present head of water *at the reservoir*, not only with reference to the needs of Church Hill, but of the whole city ; and in the subsequent part of this report I submit recommendations on the subject.

Second, as to increasing the

SUPPLY FOR THE CITY AT LARGE.

Since my appointment. I have been engaged in careful investigations and studies on this subject. I have carefully considered the many and various reports which have been made by the different engineers at different times upon the subject of supplying water to the city. I have examined all the various plans and recommendations that have been submitted to the City Council and its Water Committees. After mature reflection upon the whole subject, and upon the recommendations which my judgment has led me to adopt, I submit the plan which I now have the honor of laying before you with entire confidence that it is the best that can be adopted, that it will meet the requirements of the city, and will stand the test of time and criticism.

Richmond prossesses great advantages for providing water, in abundant supply at a cheap rate, not only for domestic and public purposes, but for those mechanical uses on which depend the growth of a city in population, enterprise, wealth and prosperity. Richmond, however, has made little comparative use of these advantages, having expended in the first outlay upon the water works only $5¼ per head of pupulation, while New York has made a *per capita* outlay of $43, Boston of $39, Jersey City of $39½, and Salem, Massachusetts, of $46.

I have found in examining the plans heretofore submitted by other engineers to the consideration of the City Council, that they are rather makeshifts, designed to meet present wants, than systems complete in themselves, looking to an ample provision for all wants, present and prospective. I have studied, in the report I have now the honor to submit, simplicity of plan, economy of cost, and capacity for supplying the largest probable wants of the city, as they may expand with the growth of population and manufacturing enterprise.

The objects to be secured are an abundant supply and good quality of water, at a sufficient head and at reasonable cost.

QUALITY OF WATER.

The quality of the water is not objected to except during freshets, when the quantity of earthy matter renders it muddy and unsuited to many purposes. Whatever is done to purify the water should be done as far as possible before it enters the pumps, so as to reduce their wear and tear. By holding the water in a state of quiescence, the mud held in suspense will be precipitated and the water become limpid. A comparative improvement in the quality of the water can be accomplished by forming a subsiding or settling pond in the river by raising the head of water above the headgates, not less than 6 feet, by means of a weir, and extending the head-race up the river to near the terminus of slackwater.

As this pond will flood some low grounds above the city property, and subject other lands further up the river to longer inundations during freshets, it will be necessary for the city to purchase additional grounds, not exceeding 45 acres. These lands, according to the report made to the Council in 1859, were then valued at $100 per acre

The pond here recommended will not only answer the purpose of partially purifying the water, but, as will hereafter be explained, of furnishing greater motive power for the pumps, and thereby increasing the supply of water to the reservoir.

To obtain perfectly limpid water at all times, however, recourse must be had to filtering; but filters and the modes of filtering vary as the matter held in suspense varies in different rivers, and in order to ascertain in this instance the most efficient and economical method, experimental tests, on a small scale, should be made. The cost of the apparatus needed for this purpose will not exceed $100.

THE SUPPLY.

From guagings taken at the reservoir during the month of January, the daily consumption was ascertained to be 2,621,345 gallons. According to the statistics of consumption in former years, as furnished by annual reports on the Water Works, the maximum daily demand during the coming summer will be from 3 to 3½ millions of gallons. To supply the the present demand the pumps are worked 16 hours daily, and to supply the demand of the coming summer it will be necessary to work them from 19 to 21 hours.

From this state of facts, it is evident that even at present, with the stoppage essential to keeping the pumps in working order, and without regard to the incidental repairs or interruptions caused by freshets and

droughts, there is not a sufficient surplus af power to insure the daily supply. This is a matter of serious importance, and it is, therefore, imperatively necessary to increase the pumping capacity of the works. Such an increase can be obtained most effectually and economically by increasing the head of water on the wheels, from 10 feet, as at present, to $15\frac{1}{2}$ feet, and by altering these wheels to high-breast wheels. By this expedient their useful effect will be double and their power trebled without changing their diameter or breadth.

This head of $15\frac{1}{2}$ feet will be obtained from the subsiding pond above recommended, by raising and strengthening the wall of the head-race, between the pump-house and the head-gates. But before the re-building of the present wheels becomes practicable, it will be requisite to erect an additional wheel and pumps to do the work of each of the other wheels, as they are respectively stopped to be re-built.

The increased head will give the wheels greater facility in overcoming the obstruction from backwater during the freshets, and will prevent any interruption that might be caused by drought, since a less quantity of water will be required to produce an equal power. The subsiding reservoir will aid in maintaining a uniform head. The interruptions during the highest freshets may be obviated by sufficiently extending the tail-race down the river, to prevent, during freshets, the formation of backwater to such an extent as to impede seriously the wording of the wheels. At the last freshet, February 1st, at a station 1,500 feet below the pump-house, the level of the water was $3\frac{3}{4}$ feet below the bottom of the wheels; during a high freshet it is $2\frac{1}{2}$ feet below, but on the 31st of September last it stood, at that station, $4\frac{3}{4}$ feet upon the wheels. On the last mentioned date, between the pump-house and that point, there was a fall of only 2 feet, 9 5-16 inches, whereas, on February 10th, there was a fall of $5\frac{3}{4}$ feet.

THE RESERVOIR.

The object of a reservoir is to maintain a constant and uniform head of water on the pipes which supply the city, by holding in store enough water to compensate for fluctuation in the inflow and outflow. The fluctuations in the supply will be inappreciable with a sufficiency of reliable pumping power; and to compensate for fluctuations in the demand, the reservoir has abundant area. The present reservoir, however, possesses one serious defect, it does not afford a sufficient head of water for the higher elevations of the city and for an efficient fire service.

There are considerable portions of the city of such elevation that the most perfect system of distribution would fail to deliver the water above the first stories of the houses. It is a maxim, laid down by the best authorities on water supply to cities, that when attainable, the head or pressure in the street mains should, when the flow in them is most rapid, be

equivalent to an elevation of 20 feet above the tops of the highest houses, in order that their uppermost stories may be directly supplied, and that, in case of fire, it may be possible to throw a stream over the tops of the highest buildings without the aid of an engine.

AN ELEVATED TANK AT THE RESERVOIR.

In order to increase the head of water, especially on Shockoe and Church Hills, to any extent desired at a comparatively moderate outlay, I recommend the construction of an elevated tank at the reservoir. The increased supply and head to be secured by this means are not only desirable for domestic purposes, but also for increasing the efficiency of the Fire Department, and at the same time decreasing its cost.

A tank near the reservoir 100 feet in diameter and 25 feet in depth would be of sufficient capacity for this purpose, and I recommend it as the cheapest and most effectual means, in connection with the increased pumping power, provided for in my recommendation on that subject, of meeting the wants of the elevated portions of the city. This tank should be so elevated above the reservoir as to afford a head that will throw a stream of water over the highest building on Shockoe and Church Hills.

DISTRIBUTION.

By taking tests at various points throughout the city, of the pressure in the mains, and comparing the altitudes of those different points with the reservoir, I have found in many places the loss of head to be excessive; which clearly demonstrates a defective distribution, caused by the insufficiency of the service mains. These defects are the result of a practice, common in this and other cities, of laying service mains of small capacity; the object being, in each instance, to stretch the pipes out to the greatest extent of the means possessed. The want of large mains has been felt in all cities in this country; and the laying down of small mains has been regarded everywhere as a great error to be corrected at any cost.

The mains throughout the city, except at a few points, are unusually small, ranging from 3 to 4 and 6 inches in diameter. The 24-inch main heretofore mentioned connects at Third street with a 16-inch main running north and south between Broad and Cary, and with a 6-inch main running down Main street. Down Cary to Ninth street the mains vary from 6 to 4 and 1½ inches; and from Ninth street there is a 3-inch main extending to Twenty-fourth street. Thus the lower portion of the city is fed from a 6-inch main on Main street and a 6, a 4 and a 3-inch pipe from the main on Broad street.

This defect in distribution can be remedied by carrying large mains, acting as feeders of the service mains, to the extremities of the city, either direct from the reservoir or from the principal supply mains as near to the

reservoir as possible, making connections at the cross streets with the smaller pipes of the street distribution.

To begin with the lower portion of the city, where the most valuable property of the merchants and manufacturers is situated, and where the ravages of fire have been most disastrous, as a part of a general plan hereafter to be carried out, and where the advantages from this plan can be at once and with less cost demonstrated, I advise the laying down on Cary street, from Third to Seventeenth streets, of a 20-inch main, and from this latter point to Venable street of a 16-inch main. With pipes of these dimensions, from suitable fire-plugs of improved make, ten streams can be thrown, equalling in volume the capacity of as many steam fire-engines, and yet retaining in the 20-inch pipes a head of 137 feet, and in the 16-inch main of 113 feet at an altitude of 180 feet below the reservoir. By connecting lateral mains of sufficient capacity with these mains, and, with the improved fire-plugs, the whole of Jeffersom Ward can be protected from fire more effectually than if possessed of as many steam fire-engines as there are plugs.

Besides reducing the expenses of the Fire Department and greatly increasing its efficiency, this constant effective head of water would furnish that part of the city with a valuable motive power, which could be extensively and usefully applied to many industrial purposes There are many trades which require an occasional use of mechanical power, and in which, as the power desired is small and not constantly needed, a steam engine cannot be afforded. By a supply pipe from the main, without the risk of fire and without any of the skill in management required in applying steam, a small water pressure engine can be set in motion at any time when required, by the mere turning of a cock.

Hydraulic engines can be used in driving small rotative machinery, such as lathes, printing presses and the like, and in many places where steam engines, on account of danger from fire, are inapplicable or inadmissable. They are also exceedingly useful and convenient when applied to hoisting purposes in warehouses, and on docks. Observations in Hamburg during nine months have demonstrated that while 5 men working diligently with the windlass hoisted in 6 hours 150 casks of 380 pounds each 15 feet high; with a hydraulic hoist and a consumption of 1,125 gallons and a head of 138 feet, two men raised 140 casks the same height in one hour, showing that manual labor in this instance was from 9 to 10 times more costly than hydraulic labor.

Hydraulic engines are superior to any other motor in simplicity and smallness of first cost, and possess the additional advantage, that the power required is always at command and the expense of using it only begins from the moment that it does service. With a head of 150 feet, 2,000 gal-

lons per hour will furnish one horse power. In cities where the water is elevated by steam, 1,000 gallons cost not less than 10 cents. If water is sold here at the same rats, one horse power will cost 20 cents per hour, and a less power a rate propotionately less. But as the cost of supply here is only $2\frac{1}{2}$ cents per 1,000 gallons, it can be furnished at a less cost than in other cities. The water engine itself acts as a perfect water meter by attaching a counter to it, showing the number of revolutions it has made and the quantity of water that has passed through it.

It cannot be doubted that the best interests of Richmond will always be subserved by fostering its manufacturing interests by economical appliances, such as have just been described. An abundance of water, at a cheap rate, is a necessity to these classes and would furnish a strong inducement to their settling in this city.

Such an increase in the supply main to the lower portion of the city, will not only be of great benefit to the localities fed directly from it, but will lesson the draft on the other mains of the city. The pipe leading direct from the reservoir to Church Hill, and the 20-inch main down Cary street are necessities calling for immediate execution

WASTE.

In connection with the question of supply must be considered the very important subject of waste.

It is evident from the comparison of the night with the day consumption, that the waste is much greater than it should be. This defect of water-works is not confined to Richmond.

The report for the city of Albany for 1865, uses this language: "A large percentage, certainly more than half of the water brought into the city, is needlessly wasted; some other cities estimate their loss from this cause far above 50 per cent, of the water supplied or drawn from the reservoir. Various expedients have been adopted to cure the evil, but without effect."

The superintendent of the water-works of this city, Mr. James L. Davis, very properly, recommends a more rigid system of inspection, looking to a correction of this serious and growing evil.

ESTIMATED COST OF IMPROVED WORKS.

The following estimate is submitted of the cost of the additional works which I have recommended. It will not be necessary for all of this cost to be incurred in the first instance. A considerable part of it may be deferred to await the expanding necessities of the city. The cost of the works which will be necessary at the beginning will be about $496,000. The remaining items of the estimate, to be incurred as the requirements of the city shall hereafter demand, will be about $317,000.

My estimate of the cost of the additional works is as follows:

CHURCH HILL			
Connecting the 24-inch main with the reservoir.......		$8,240	
Church Hill service, including improved fire hydrants.		27,600	
EXTENSION OF WORKS.			
Forty-five acres of land including commission, &c......		$8,500	
Weir and new headgates		68,000	
Wall of head-race................ ... ., ...		26,000	
New wheel and pumps, capable of delivering 160,000 gallons per hour into the reservoir, with addition to pump-house and supply main to pumps...............		54,000	
36-inch pump main, with stop-cocks, &c		61,600	
Tail-race..........		28,000	
The high service Reservoir or Tank, to contain one million gallons, the top of it to be, say 75 feet above the level of the reservoir		160,000	
DISTRIBUTION.			
670 tons of 2 and 16-inch mains at $58	$38,860		
Laying same, including material, fire hydrants, stop-cocks and extra castings.....	15,000		
		53,860	
			495,800
5,000 feet of 36-inch main, from reservoir to Main and Henry streets.....		86,200	
2,000 feet of 36-inch main, along Henry, from Main to Clay streets		34,500	
15,000 feet of 12 and 8-inch mains (the present pump mains), taking same up and relaying them...		12,000	
			132,700
			$628,500
5,000 feet of 24-inch main, made available by laying the 36-inch main, taking some up and relaying it...		10,000	
Re-organizing distribution in remaining parts of the city and for fire hydrants, ...		40,000	
New wheels and pumps and re-building pump-house.		132,000	
			182,000
			$813,000

It will be seen that in the foregoing estimate, I have provided for replacing the present pump mains with *one* 36-inch main, and for using those proposed to be taken up in the distribution service. The present pump mains are 15,000 feet long, and weigh not less than 400 tons, with 8 tons of lead. The use of them in distribution would save an outlay there of $18,000, so that the net cost of new 36-inch pump main ($61,600) would be reduced to $43,600

The present pump mains having only one-fourth the capacity of the proposed 36-inch main cost $65,000.

If we add to the entire cost of the immediate and future additional works which I have recommended, the net cost of the works as they now are, the aggregate will amount to $870,800, viz :

Original works (net)...................	$190,000
Proposed works.............................	813,000
	$1,003,000

This is a small cost for water works compared with what has been incurred in other cities. The city of Salem, Massachusetts, for instance, whose water works have been most recently constructed, having an assessed real estate of $21,987,000, a population of 24,117, and a capacity in water works of $2\frac{1}{2}$ millions of gallons in 12 hours, expended in the construction of the latter the sum of $1,100,000

Richmond has an assessed real estate of $26,150,000, and a population of 51,087. My plan proposes to increase the capacity of her water works to $7\frac{1}{2}$ million gallons in 12 hours, at a cost of all works from the beginning, of $1,003,000 The outlay does not seem unreasonable in the light of this comparison.

The policy of making provision on such a scale as will meet the largest probable demands of the future for water, is approved by all who have had any experience on this subject. On this point I cannot do better than repeat some remarks which were addressed to the citizens of Boston in 1845 in relation to the same matter. The Boston Commissoners said : "We do not know of an instance where the largest provision has been made, and the advantages flowing from it fairly tested, in which it has failed to produce a general conviction of its superior usefulness, and entire satisfaction that the extra cost of procuring an abundant over an inferior supply was a judicious expenditure. And we have therefore not the least doubt, that if the city adopts the plan of providing $7\frac{1}{2}$ million gallons per day, when the work is fairly brought into use and its benefits developed, there will be far more surprise that any should have questioned its propriety, than that so large a supply was considered necessary." In this same city of Boston many contended that one million five hundred thousand gallons per day (for 115,000 inhabitants) would be an abundant supply, and an engineer who was employed in making surveys and examinations for obtaining water, said in a written statement presented to a committee of the legislature of Massachusetts, that "ten or twelve years would elapse before two million one hundred thousand gallons per day would be likely to be consumed." Yet in spite of these predictions, the daily consumption, during the hottest part of the summer, 1851, reached eight million gallons per day

(Water was introduced into the city of Boston and the event celebrated October 25th, 1848.)

While the Croton aqueduct of New York was in course of construction the chief engineer, in a report (June 1st, 1839) upon a plan for crossing Manhattan Valley, remarked: "In making the estimate for four pipes, I have supposed an average time in putting down the remaining pipes of sixty years would elapse before the wants of the city will require the full operation of the aqueduct." But in the annual report of the Croton Aqueduct Department, dated 31st December, 1850, only a little more than eight years after the first introduction of the water, this startling announcement appears: "*This Board* now warns the Common Council, and through it every citizen, *that the last drop of water which the works in their present state can supply, is now delivered in the city*" The quantity then delivered by the Croton aqueduct was thirty million gallons per day, or sixty gallons for each individual of the whole population of the city of New York, and probably less than three-fourths of the whole number had the water furnished to them.

When the Lake Tunnel for supplying water to the city of Chicago was constructed, provisions was made for its future extension, westward, in such a manner as to double its capacity above what it was supposed would be the wants of the city, no one dreaming that its use would be called for to the additional extent for many years. But the demand for its whole capacity has already occurred, and they are now so constructing the works as to provide for a daily supply of 100 million gallons of water to the city, with a view to meeting, not only the ordinary consumption, but to supplying the wants of the Fire Department. All the principal cities of this and the other continent are now either enlarging their water works or looking for an increased supply.

New York city, with a population of 926,341, has a supply of 64 million gallons per day; having more than double the original supply to the Croton aqueduct.

London is providing for a supply of 78 gallons for each person.

This large provision of water is everywhere deemed essential, not only to supplying a necessary of life, but as indispensable to establishing control over fire, and to preserving the health of the population.

Sources of Taxation for Estimated Outlay.

In adjusting the taxation requisite to provide for this additional outlay for water supply, I venture to suggest the enquiry, whether it is expedient to levy the tax exclusively upon consumption. Every piece of real property in the city is enhanced in value by the facilities of water provided by the works of the city. The property all sells for more and is worth more. in consequence of the water privileges it possesses, than if these did not exist. The statement applies as truthfully to vacant property as to that which is improved. There is no equitable reason why vacant lots should not be taxed for the first cost of their water privileges. Vacant and improved real property should, of right, compensate the city for the additional value which it derives from the works and pipes which bring water into its vicinity. In nearly all other cities having water works, a tax is laid of so many cents per foot of pipe in front of it, or a certain fraction of a cent per square foot of the lot taxed. This tax is found to be of great service in strengthening the credit and finances of the cities. Such a tax, at the rate of one-fifth of a cent per square foot of lot, would bring, in Richmond, and annual revenue of $70,000; which would discharge the interest of the loan made for the new works proposed, and provide a handsome sinking fund for the grandual liquidation of the debt. Such a tax would be regarded with great favor by capitalists, and would furnish a permanent and substantial basis of credit in borrowing the money required. Such a tax would amply provide for the original cost of the additional works recommended, leaving the tax on consumption to meet the annual cost of supplying the water and maintaining the works. If, moreover, water be furnished by the city as a motor for the lighter machinery used by the mercantile and manufacturing classes. a large revenue could be derived from this source, even if the charge should be put at as low a rate as ten cents per hour for each horse-power used. The revenue derived from this source cannot now be estimated; but it would rapidly increase from the time that this application of water shonld be inaugurated, and would soon rise to a considerable annual amount. This application of water power would create a large indireet revenue by encouraging the growth, in the heart of the city, of many branches of manufacture not now existing, and thus would add greatly to the population, enterprise and taxable values of the city.

All of which is respectfully submitted by

Your obedient servant,

JOSEPH J. HEINDL.